# The Individual Basic Facts Assessment Tool

Sandi Tait-McCutcheon
*Victoria University of Wellington*
<sandi.mccutcheon@vuw.ac.nz>

Michael Drake
*Victoria University of Wellington*
<michael.drake@vuw.ac.nz>

There is an identified and growing need for a levelled diagnostic basic facts assessment tool that provides teachers with formative information about students' mastery of a broad range of basic fact sets. The Individual Basic Facts Assessment tool has been iteratively and cumulatively developed, trialled, and refined with input from teachers and students to meet that need. The development of the tool, results from test trials, and our next steps are described in this article.

The importance of students knowing their mathematics basic facts is not a new phenomenon. The instant recall of basic fact knowledge is acknowledged as an important goal for mathematics education and an essential precursor for students' success in mathematics (Boaler, 2012; Ministry of Education [MoE], 2007a; Tait-McCutcheon, Drake, & Sherley, 2011; van de Walle, 2009; van de Walle, Karp, & Bay-Williams, 2013). Students' fluency with sophisticated tasks such as problem solving and higher-order processing is enhanced by their ability to instantly recall basic facts (Kilpatrick, Swafford, & Findell, 2001). Their short-term memory is freed-up and they are better positioned to focus on the more challenging strategic aspects of the task (Kling & Bay-Williams, 2014; Neill, 2008). Research has also acknowledged a strong correlation between basic facts fluency and mathematics achievement (Kilpatrick et al., 2001).

While the importance of being able to recall basic facts is well established, how this is best achieved has not been well defined. Traditional testing of basic facts has occurred through timed tests of short duration whereby students attempt to solve a specific number of addition, subtraction, multiplication, and/or division problems, randomly written in terms of difficulty (Kling & Bay-Williams, 2014). For example 50 facts within three minutes (Clarke & Holmes, 2011). Such an approach to testing is problematic and unlikely to elicit a true picture of student achievement (Crooks, 1988).

Evidence from previous research into the teaching, learning, and assessing of basic facts in New Zealand (Sherley & Tait-McCutcheon, 2008; Tait-McCutcheon et al., 2011), indicated that practice in schools, while changing, too often had the limited notion that learning basic facts meant learning the multiplication facts. Internationally, assessment tools and teaching interventions have focussed predominantly on multiplication facts (Clarke & Holmes, 2011; Kling & Bay-Williams, 2014; Skarr et al., 2014). As such, there is a strong possibility of a disconnect between the test content and student's class work. Some students could be repeatedly tested on facts they already know whilst others could be tested on facts related to operations they have very little understanding of, or use for.

Our stance is that basic facts are basic because they are fundamental and underpin the student's next learning steps, not because they are easy. They are facts in that they are pieces of mathematical information that are committed to and can be retrieved from long-term memory. The definition of basic facts in this research comes from Neill (2008) "any number or mathematical fact (or idea) that can be instantly recalled without having to resort to a strategy to derive it (p. 19). One implication of this definition is that the notion of *basic facts* is not a stable, fixed body of knowledge but is contextual as the facts being learned change with age and developing mathematical concepts. A second implication is

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that because students need to continually increase their fact mastery, all teachers need a robust basic facts programme as an integral part of their mathematics curriculum.

In relation to the issue of timed basic facts tests, McCloskey (2014) asked, "[C]ould the timed test be changed into a different form of performance with more meaningful assessment purposes and yet maintain the traditionalised purpose that teachers and parents seem to value?" (p. 35). This paper is a response to McCloskey's question. It outlines the development and use of the Individual Basic Facts Assessment (IBFA), a tool for identifying a students' current level of basic fact knowledge and fluency, an approach to basic fact testing referred to in Tait-McCutcheon et al. (2011).

## Uses, Utility, And Apprehension

The authors concerns regarding the questionability of timed tests eliciting a true picture of student achievement have been documented in the literature. Three themes identified from the literature include: assessment measures and uses, what is valued, and the relationship between timed tests and math anxiety.

One assumption commonly made about timed basic facts tests is that correct answers are derived from knowledge. However, because the time given is to complete the whole test students could immediately recall the answers they know and then use a mix of efficient or inefficient strategies to determine other answers (Tait-McCutcheon et al., 2011). For example, Clarke and Holmes (2011) gave students three minutes to complete the test to ensure "knowledge rather than strategisation of solutions" (p. 205), but, this approach assumes that students used the same amount of time to solve each problem. As Kling and Bay-Williams (2014), contended timed testing "offers little insight about how flexible students are in their use of strategies or even which strategies a student selects" (p. 490).

The dilemma of speed versus accuracy and what gets valued is the second theme identified from literature. Popham (2008) suggested there was no value in "pressuring kids to be math perfect in minutes" (p. 87). Seeley (2009) warned against "overemphasizing fast fact recall at the expense of problem solving and conceptual experiences" because such emphasis can give students "a distorted idea of the nature of mathematics and of their ability to do mathematics" (p. 2). The danger being that the speed in which the test was completed could be valued more than the accuracy of the answers, speed could be erroneously equated with mathematical ability or fluency, and students could interpret their responsibility as having to be quick (Boaler, 2012; Kling & Bay-Williams, 2014).

The third theme is the relationship between timed tests and math anxiety. Boaler (2012) claimed a "direct link between timed tests and the development of math anxiety" (p. 2). Timed tests have been shown to trigger math anxiety in all students and the claim from Kling and Bay-Williams (2014) is that "some of our best mathematical thinkers are often those most negatively influenced by timed testing" (p. 490). Stress can block students working memory, causing symptoms similar to stage fright and making even familiar facts unretrievable (Beilock, 2011). The more aware students became of their inability to recall known facts the more apprehensive they became about their performance and results. The stress or anxiety caused by the timed test conditions may pressure students to revert to less efficient strategies such as finger counting, head bobbing, or touch point counting (van der Walle, 2009). For some students the prospect of doing a timed test could be enough to elicit a negative emotional response, with many disliking "not only tests, but also math" (Popham, 2008, p. 87).

Despite the noted disadvantages of traditional timed tests, the assessment of student's basic facts knowledge remains a requirement and expectation for many teachers and parents (McCloskey, 2014; Seeley, 2009). Our aim was to develop and trial an assessment tool that more accurately measured basic fact recall, provided cleaner data, identified the use of knowledge or strategy, and reduced anxiety.

## Method

Design-based research (D-BR) was the most appropriate methodological frame for this research for the following reasons: the iterative, cumulative, and cyclic nature of the research and theory development, the positioning of the research within the naturally occurring phenomena of classrooms, and the flexibility of the research design (Gravemeijer & van Eerde, 2009; Kennedy-Clark, 2013). Gravemeijer and Cobb (2006) used the following adage to explore the underlying philosophy of design research: "if you want to change something, you have to understand it, and it you want to understand something, you have to change it" (p. 45). The researchers of this study determined they wanted to change the current tools for testing students' basic fact knowledge recall. Once the affordances and limitations of current tools were better understood, we set about designing, trialling, understanding, and improving the IBFA tool.

The theoretical rationale in this study was to understand the teaching, learning, and assessing of basic facts, the applied rationale was to use our empirically supported theories to influence how basic facts are taught, learned, and assessed in New Zealand schools. Context theory related to the challenges and opportunities presented in designing an alternative IBFA tool and outcomes theory related to the outcomes associated with the intervention to improve the teaching, learning, and assessment of basic facts.

### *Research Settings and Participants*

Four schools participated in phases one or two of the IBFA tool design and development. Table 1 provides relevant data of the schools, teacher participants, and students.

Table 1
*The research settings and participants*

| School Name (Pseudonym) | Decile | Category | Teachers | Students | Year Group |
|---|---|---|---|---|---|
| Ponga Primary | 8 | Full Primary | 1 | 23 | 5 - 8 |
| Nikau Intermediate | 4 | Intermediate | 4 | 96 | 7 - 8 |
| Nikau Secondary | 6 | Secondary | 3 | 63 | 9 |
| Rimu Intermediate | 8 | Full Primary | 3 | 81 | 7 - 8 |

### *Data collection and analysis*

A mixed methods data collection occurred to allow for a more robust understanding of the learning environment (The Design-Based Research Collective, 2003). Forms of data included observations from researchers, teachers, and students, student test papers, and interviews between researchers, teachers, and students. Data were analysed immediately, continuously and retrospectively alongside literature reviews coupled with the systematic and purposeful implementation of research methods (Wang & Hannafin, 2005).

Patterns, thoughts, and items of interest were noted during the analysis phase. Data were eyeballed "to see what jumps out" (Miles, Huberman, & Saldaňa, 2014, p. 117). For example, each set of stage results were considered for unusual results and explored in relation to the Number Framework (MoE, 2007a), and items located in nearby stages. This process could lead to an item being moved between stages. The design and revision of the IBFA questions were based on the researchers' anticipations of which stages to place each problem and in what order. As such, "each cycle in the study is a piece of research in itself" (Plomp, 2007, p. 25) that contributed to the growing body of knowledge.

Formative evaluation of both quantitative and qualitative data informed the improvement and refinement of the IBFA tool and guidelines (Kennedy-Clark, 2013). This allowed us to measure the effects of the test and to develop richer pictures of teacher and student knowledge acquisition. A mixed methods approach increased the credibility and adaptability of the research allowing for retrospective analysis and formative evaluation. The positionings of the researchers and teachers within the study also ensured adaptability (Plomp, 2007). Researchers took on the roles of designer, advisor and facilitator without losing sight of being a researcher, and teachers took on the role of researcher, designer, and advisor without losing sight of being a teacher. The inclusion of different expert groups within the study provided an extended degree of rigor and mitigated issues of accessibility (Wang & Hannafin, 2005).

## IBFA Tool Design and Development

The IBFA tool was designed, elaborated, trialed, and revised in an attempt to further understand and improve the educational processes of assessing basic facts. The guidelines for understanding and administering the tool are as follows:

> The response time for each item was aligned with the NDP expectations of what knowing means and allowed students 4 seconds to answer one question rather than 5 minutes to answer 100. The assessment includes basic-facts questions written as both number problems (e.g., 9+9 =, which is read as "nine plus nine equals") and problems written in words (e.g. double what is ten?). To alleviate any prerequisite literacy requirement that could adversely affect students' mathematical proficiency each item is read aloud to the class as well as displayed visually on a timed slideshow. As it is possible for students to strategise within the four seconds allocated for each item students are asked to annotate their answers with a "k" if they know the answer instantly or with an "s" if they strategise. (Tait-McCutcheon et al., 2011, p. 336)

The first version was designed to meet the following criteria. First to assess facts derived from the Number Framework (MoE, 2007a) and related to The New Zealand Curriculum (MoE, 2007b). Secondly, to provide a visual and aural, readily administered and easily marked test, useable with a whole class that offered reliable, relevant data that could be interpreted and actioned by students, teachers, and parents. Thirdly, to position students as active constructors of meaning by focussing them on individual facts, rather than a collection of facts, addressing the *amount of time* issue for an individual fact, and determining if an answer resulted from knowledge, strategy, or a combination. Fourthly, to address commonly recognised problems that students have when learning a particular set of facts and to include facts commonly found to be problematic and be sufficient in number to identify whether or not a student knows a particular set of facts. Fifthly, to provide results that identify students' next learning steps, teachers next teaching steps, and a clean stage descriptor for reporting purposes.

## *IBFA Version One (V1)*

IBFA V1 was trialled at Ponga Primary School as part of the research described in Tait-McCutcheon et al. (2011). Given the sample size the tool was found to be fit for purpose, however, the design process identified issues that would need to be addressed in larger scale trialling. For example, the Number Framework (MoE, 2007a, pp. 21 & 22) identifies that at Stage 6 students should know their multiplication facts and some corresponding division facts but not know all of their division facts until Stage 7, so it was unclear which division facts should be located at which stage.

The second trialling of V1 occurred at Nikau Intermediate and Secondary Schools. Teachers at both schools indicated the format was suitable for a range of ages and student abilities. However, the time set for the items (4 seconds) was an issue at the higher stages. While the time allocation was considered the maximum that should be allowed for knowledge recall, a review of the items indicated that concepts such as common factors needed to be found using a mix of knowledge recall and strategising. Such items were either simplified to retain the skill but better target knowledge recall and take less time, or were replaced with items from a different fact set. Also identified was a trend relating to start and change unknown formats (Sarama & Clements 2009). Students tended to find these harder than result unknown, but it was unclear whether this was a teaching issue or due to item difficulty. Clusters of items were explored to identify the appropriate location of particular sets of facts. For example, a cluster of items relating to the subtraction facts to 10 was spread over Stages 4 and 5. Results suggested that these were better located at Stage 5. For the multiplication and division facts over Stages 6 and 7, the numbers in the Stage 6 items were simplified and result unknown format applied to determine if this gave better discrimination.

Matters outside the initial scope of the research were also identified. For example, some students noted their correct answers as a total out of 60 rather than identifying what stage, which sets of facts they had mastered, and what their next learning steps were. Other classes had not used the ‘K’ or ‘S’ notations to indicate if they knew the answer or needed to work it out. The instructions for teachers were revised, as was the answer sheet, to ensure students and teachers better understood the purpose behind the test’s structure and to ensure data from different classes and schools were of a similar standard.

Researchers and teachers made significant contributions to further developing the content of the IBFA V1 and the theories underpinning the use of it (Gravemeijer & van Eerde, 2009). It was important to have synchronicity between both groups as to what the data was telling us and what we were identifying as next teaching and learning steps. As Mason (2002) suggested, this “process of refinement” (p. 181) was also part of the research as teachers reported back what they noticed and provided both practical and scientific ways to enhance the next research phase and their teaching (Gravemeijer & van Eerde, 2009). As such, the creation of V2 started to move the IBFA forward from the Number Framework to include lessons from trialling.

## *IBFA Version 2 (V2)*

Version 2 was trialled at Rimu School. Students marked their own papers with later re-marking by the researchers. Twenty-six papers (32%) were found to have errors. One particular problem with student marking occurred when students ‘lost track’ of where they were up to in the test and produced a set of answers that were misplaced by one or two.

Another was when students put an unusual format for an answer. Teachers can adapt for such issues but students struggled to do so.

The changes introduced to Version 1 created *cleaner* results – in that there were fewer papers with *odd men out* (single items that many students answered incorrectly at a stage or single items correct at a stage). Fewer *random* results were found (individual correct items beyond the previous pattern of correct items). These processes suggested that the changes more correctly positioned sets of facts at a developmental stage and that the items were better targeting likely problems when learning a set of facts. Clearer trends were also evident. For example, at Stage 6, it was common to find, as Neill (2008) reflected, students who knew their multiplication and division facts but did not know their addition and subtraction facts to and from 20 – with particular classes tending to have this problem.

To identify items that were easier or harder than the rest at a stage, papers with 1 to 3 or 7 to 9 correct at a stage, and paired items (such as, "19 – □ = 8" and "8 + what equals 19?") were also analysed. For example, the cluster of items on the multiplication and division facts over stages 6 and 7 still tended to be answered consistently – all correct or incorrect, so these were moved to Stage 6 for V3. In V2, students again found start and change unknown formats slightly harder than result unknown, but not to the point where such items warranted location at a higher developmental stage.

Finally, the sets of facts assessed in V2 were mapped back to items in the IBFA, the Number Framework, and other fact frameworks (see NZCER, 2015; Van de Walle et al., 2013). This resulted in alterations to several items and the development of additional items at the higher stages. The sets of facts addressed in V3, and their related test question numbers can be found in Appendix A.

## Conclusion

IBFA is a basic facts test designed to be used concurrently with other forms of assessment to support the ongoing learning of basic facts. Developmentally, the IBFA is progressing towards meeting its initial aims of providing teachers with a reliable assessment capable of providing information about students' mastery of a broad range of basic fact sets. Using a PowerPoint that only allows 4 seconds per question has ensured that students are not able to strategise across a collection of items or take a long time over any one item. Having the teacher read out the question alongside the visual prompt has made the assessment accessible to a broad range of students. With both V1 and V2, teachers report they were able to quickly gather information from students and that the data collected was easy to mark, interpret, and use to support their teaching of basic facts. V2 also allows cleaner stage decisions to be made as there are fewer *odd men out* – individual questions at a stage which are the only item that a number of students get right or wrong.

Our next phase of development is to trial Version 3 (V3) across a wide range of ages, including students in rural and low decile schools. One purpose is to evaluate the changes made to V2, in particular whether improved instructions and information about using the 'K' and 'S' codes along with better placed items show a stronger transition from knowledge recall to strategising. A second purpose is to move the research forward to include a teaching intervention based on Tait-McCutcheon et al. (2011), for which a supporting resource booklet has been written (Drake, 2014). We welcome teachers and researchers who are interested in trialling the IBFA or developing a basic facts programme based on these materials to contact either author.

# References

Beilock, S. (2011). *Choke: What the secrets of the brain reveal about getting it right when you have to*. New York: Simon & Schuster, Free Press.

Boaler, J. (2012). Timed tests and the development of math anxiety. *Education Week*. Retrieved http://www.edweek.org/ew/articles/2012/07/03/36boaler.h31.html

Clarke, S. & Holmes, M. (2011). Mastering basic facts? I don't need to learn them because I can work them out. J. Clark, B. Kissane, J. Mousley, T. Spencer & S. Thornton (Eds.), *Mathematics: Traditions and [New] Practices* (Proceedings of the 34th annual conference of the Mathematics Education Research Group of Australasia, Alice Springs). Adelaide: MERGA.

Crooks, T. J. (1988). The impact of classroom evaluation practices on students. *Review of Educational Research, 6*, 101–116.

Drake, M. (Unpublished). *Learning basic number facts: A DIY guide for parents, learners, and teachers.*

Gravemeijer, K., & Cobb, P. (2006). Design research from a learning design perspective. In J. van den Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.), *Educational design research* (pp. 45-85). New York, NY: Routledge.

Gravemeijer, K. & van Eerde, H. H. H. (2009). Design research as a means for building a knowledge base for teachers and teaching in mathematics education. *The Elementary School Journal, 109*(5), 510-524.

Kennedy-Clark, S. (2013). Research by design: design-based research and the higher degree research student. *Journal of Learning Design, 6*(2), 26-32.

Kilpatrick, J., Swafford, J., & Findell, B. (2001). *Adding it up: Helping children learn mathematics.* Washington: National Academy Press.

Kling, G. & Bay-Williams, J. M. (2014). Assessing basic fact fluency. *Teaching Children Mathematics, 20*(8), 489-497.

McCloskey, A. (2013). The promise of ritual: A lens for understanding persistent practices in mathematics classrooms. *Educational Studies in Mathematics, 86*, 19-38. doi: 10.1007/s10649-013-9520-4

Mason, J. (2002). *Researching your own practice: the discipline of noticing*. London: Routledge Falmer.

Miles, M. B., Huberman, A. M., & Saldaňa, J. (2014). *Qualitative data analysis: A methods sourcebook* (3rd Edn), Los Angeles: Sage Publications

Ministry of Education. (2007a). *Book 1: The number framework.* Wellington: Author.

Ministry of Education. (2007b). *Book 2: The diagnostic interview*. New Zealand: Author.

New Zealand Council for Education Research (NZCER). (2015) Basic facts concept map. Retrieved April 10, 2010, from http://arb.nzcer.org.nz/supportmaterials/maths/concept_map_basic_facts.php.

Neill, A. (2008). Basic facts: Start with strategies, move onto memorisation. *Set 3*, 19-24.

Plomp, T. (2007). Educational design-based research: An introduction. In T. Plomp & N. Nieveen (Eds.), *An Introduction to Educational Design-based research*. pp. 9-33. SLO: Netherlands ICD

Popham, W. J. (2008). Timed tests for tykes. *Educational Leadership, 65*(8), 86-87.

Ramirez, G., Gunderson, E., Levine, S., & Beilock, S. (2013): Math Anxiety, Working Memory, and Math Achievement in Early Elementary School, *Journal of Cognition and Development, 14*:2, 187-202. doi.org/10.1080/15248372.2012.664593

Sarama, J., & Clements, D. H. (2009). *Early childhood mathematics education research: Learning trajectories for young children*. New York: Routledge.

Seeley, C. (2009). Faster isn't smarter: The trap of timed tests. *Maths Solutions Message 18*. Retrieved http://www.mctm.org/mespa/FasterIsntSmarter.pdf

Sherley, B., & Tait-McCutcheon, S. L. (2008). *Practice +assess ≠ knowledge: Basic facts and spelling lists.* Retrieved http://www.nzmaths.co.nz/findings-nz-numeracy-developmentprojects- 2007?parent_node.

Skarr, A., Zielinski, K., Ruwe, K., Sharp, H., Williams, R. L., & McLaughlin, T. F. (2014). The effects of direct instruction flashcard and math racetrack procedures on mastery of basic multiplication facts by three elementary school students. *Education and Treatment of Children, 37*(1), 77-93. doi: 10.1353/etc.2014.0007

Tait-McCutcheon, S. L., Drake, M. & Sherley, B. (2011). From direct instruction to active construction: Teaching and learning basic facts. *Mathematics Education Research Journal, 23*, 321–345. doi: 10.1007/s13394-011-0018-z

The Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1), 5-8.

Van de Walle, J. (2009). *Reform mathematics vs. the basics: Understanding the conflict and dealing with it.* Retrieved http://www.mathematicallysane.com/analysis/reformvsbasics.asp.

Van de Walle, J., Karp, K., & Bay-Williams, J. (2013). *Elementary and middle school mathematics: Teaching developmentally* (8th ed.). New Jersey: Pearson.
Wang, F., & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology, Research and Development, 53*(4), 5-23.

## Appendix A IBFA Fact Sets

| Curriculum Level | Numeracy Stage | Fact sets assessed (Item numbers in brackets) |
|---|---|---|
| One | Three: Counting | Addition & subtraction facts to five (1 - 4) Zero facts (5, 6)<br>Doubles to 10 (7, 8, 10)<br>Plus one facts (Number sequence) (9) |
| | Four: Advanced Counting | Addition and subtraction facts to 10 (1, 2)<br>Doubles to, and halves from 20 (3 - 5)<br>Ten and facts (teen facts) (6, 7)<br>Multiples of 10 that add to 100 (8 - 10) |
| Two | Five: Early Additive | Addition facts to 20 (1, 2) Subtraction facts from 10 (3, 4)<br>Multiplication facts for the 0, 1, 2, 5, and 10 times tables (5 - 10)<br>Multiples of 100 that add to 1000 (11) |
| Three | Six: Advanced Additive | Addition and subtraction facts to 20 (1 – 5)<br>Multiplication facts to 100 and corresponding division facts (6 – 12)<br>Square numbers (13)<br>Compatible numbers to 100 (14) |
| Four | Seven: Advanced Multiplicative | Multiplication & division facts beyond 10 × 10, facts with tens, hundreds and thousands (1 – 3)<br>Division with remainder (4)<br>Fraction↔ decimal↔ percentage conversions for 1/2 - 1/5, 1/10 (5 – 8)<br>Square roots of numbers to 100 (9)<br>Quantities of an amount (10, 11)<br>Factors and multiples (12) Factors (including primes) to 100 (13)<br>Compatible numbers to 1 (14) |
| Five | Eight: Advanced Proportional | Integer facts for +/-/×/÷ (1 – 4)<br>Fraction↔decimal↔percentage conversions (5, 6)<br>Simple powers of numbers to 10 (7, 8)<br>Common multiples & lowest common multiples to 10 (9 & 14)<br>Divisibility rules for 2, 3, 4, 5, 6, 8, 9, and 10 times tables (10, 11)<br>Common factors and highest common factor to 100 (12, 13) |